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## CORRELATION OF COLOUR CHARACTERS IN RICE

BY

G. P. HECTOR, M.A., B. Sc

*Economic Botanist to the Government of Bengal*

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AGRICULTURAL RESEARCH INSTITUTE, PUSA

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# CORRELATION OF COLOUR CHARACTERS IN RICE.

BY

G. P. HECTOR, M.A., B.Sc.,

*Economic Botanist to the Government of Bengal.*

[Received for publication on 10th June, 1921.]

In the account given below, the inheritance of the following characters in the rice plant is discussed.

(1) Colour characters due to soluble pigment occurring in various parts of the growing plant.

(2) Colour of the mature kernel, *i.e.*, the husked grain.

(3) Colour of the mature inner glumes, *i.e.*, the husk.

Most of the above characters have been found to give definite Mendelian ratios, and many have been proved to be inherited in groups or patterns and not independently. It is mainly from the latter point of view that they are described in the present paper.

The characters noted above will be taken up in order.

## Colour characters due to dissolved pigment.

A large number of varieties of rice are characterized by the presence of coloured pigment distributed throughout various parts of the plant, but the majority of varieties are devoid of colour and are wholly green during the vegetative period. The colour is due to soluble pigment dissolved in the cell sap. This colour can be made a basis for classification into (1) coloured varieties and (2) green or colourless.

The colours concerned range from reds through blues to deep purple ; the difference in colour being generally due simply to the degree of concentration, but in certain cases apparently to their being in themselves intrinsically different.

The chief situations of this colour are :—

(1) The leaf-sheath, pulvinus of leaf, ligule and auricles.

(2) The internode.

(3) The small outer glumes.

(4) Apiculus of the inner glumes.

(5) The inner glumes as distinct from the apiculus.

(6) The stigma.

The above will be readily understood by a reference to the plate.

The varieties so far studied at Dacca with reference to the distribution of these colours may be broadly grouped as follows :—

(1) Varieties with leaf-sheaths, apiculus of glumes and stigma coloured.

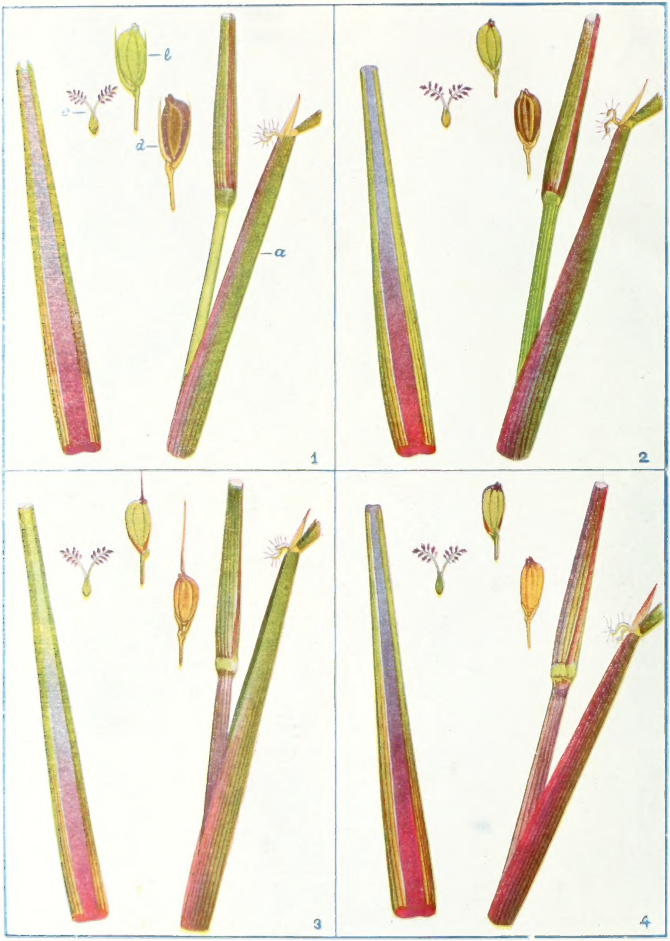
(2) Leaf-sheaths and apiculus of glumes coloured, but stigma colourless (white).

(3) Apiculus of glumes only coloured.

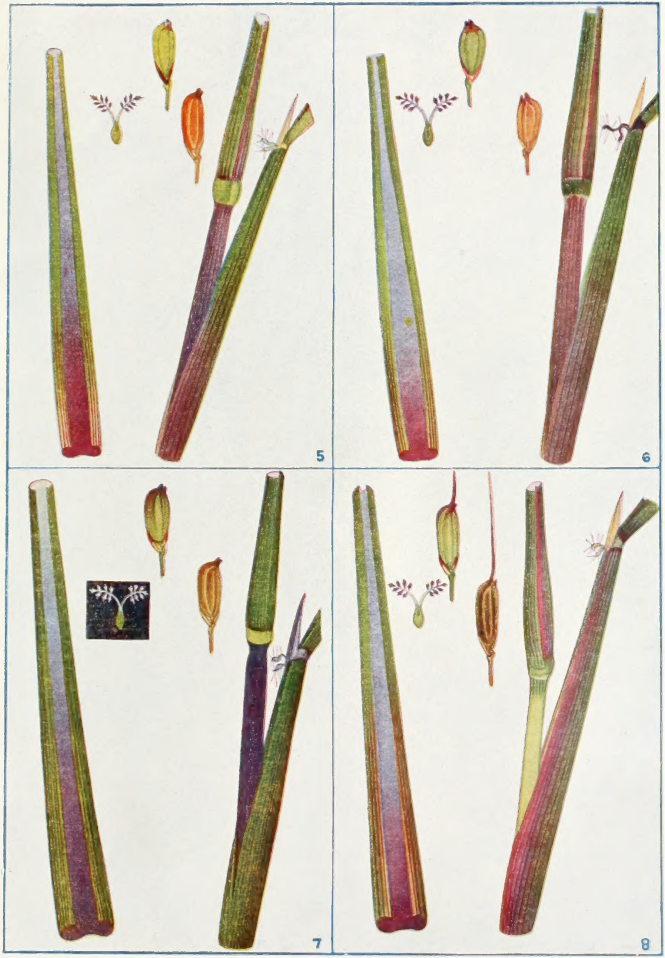
Each of these groups may have colour in other parts also, such as the nodes, internodes, outer glumes and body of inner glumes as distinct from the small spot of colour at the apex, the so-called apiculus. Indeed the colour is found in so many combinations, each breeding true in pure-line cultures, that any satisfactory grouping is not possible. Types can only be described. Moreover, varieties which outwardly appear similar in colour characters may be found on investigation to have the colour situated in different parts of the cell-anatomy ; as, for example, in the internode and leaf-sheath, where varieties which outwardly appear the same may have the colour situated in the epidermal layer only, or in the bundle sheaths only, or in both together.

Early results,[1] obtained chiefly from the analysis of the offspring of natural crosses, showed that these colours were frequently due to the interaction of several factors, and that they were often combined into patterns which were inherited as a whole. In order to investigate the mode of inheritance of these colour patterns more thoroughly, a series of crosses were made between a number of variously coloured paddies and green varieties, and the data discussed below have all been derived from the results of these experiments. In the first place, the inheritance of colour in each of the various situations referred to will be described without reference to the others. The combinations of the colour characters will be discussed later.

[1] Hector, G. P. "Observations on the Inheritance of Anthocyan Pigment in Paddy Varieties." *Mem. Dept. Agri. India, Bot. Ser.*, VIII, no. 2, Nov. 1916.




1, PANKHIRAJ; 2, MATICHAK; 3, NOACHUR; 4, MURAMAGAR;
*a*, Internode with leaf-sheath, ligule and auricles.




5, SURJAMUKHI; 6, BAILABAKRI; 7, AGARTOLLAH; 8, CHITTAGONG.
*b*, spikelet at flowering time; *c*, stigma; *d*, mature spikelet.

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### Colour in the leaf-sheath.

The development of colour varies greatly. It is generally developed mainly in the epidermis and underlying layers of the inside of the leaf-sheath, in the epidermis and adjacent layers of the outside of the leaf-sheath, in the tissues surrounding the bundles (bundle-sheaths), and may also occur scattered in the general parenchyma. Frequently, on the outside of the leaf-sheath it is found only in the epidermal layer towards the margin, thus producing the conspicuous red line seen in some varieties running down the overlapping edge of the sheath. These different colour situations may be due to different factors, but in our experiments, coloured leaf-sheath means simply the presence of colour of any sort visible from the outside to the naked eye. This colour in the leaf-sheath has always been found dominant to its absence, and to segregate in $F_2$ in a simple 3 : 1 ratio, a 9 : 7 ratio, a 27 : 37 ratio, and in a 15 : 1 ratio. Thus the colour is due either to a simple factor or to two or more interacting factors.

The table gives details of crosses in which these various ratios have been obtained :—

| Theoretical ratio | Variety Colour × no colour | $F_2$ Colour : no colour | Observed ratio Colour : no colour |
|---|---|---|---|
| 3 : 1 | Pankhiraj × Pookhi | Total 5 families<br>1,015 : 317 | 3·2 : 1 |
| | Surjamukhi × Pookhi | One family<br>731 : 261 | 2·8 : 1 |
| | Muramagar × Pookhi | Total 4 families<br>2,198 : 818 | 2·6 : 1 |
| | Matichak × Pookhi | Total 9 families<br>2,703 : 829 | 3·2 : 1 |
| | Bailabakri × Pookhi | Total 7 families<br>3,485 : 1,202 | 2·8 : 1 |
| 9 : 7<br>(1·2 : 1) | Agartollah × C 25 | Total 4 families<br>2,670 : 1,999 | 1·3 : 1 |
| 27 : 37<br>(1 : 1·3) | C 9 × C 25 | Total 2 families<br>644 : 686 | 1 : 1·06 |
| 15 : 1 | Noachur × Pookhi | Total 3 families<br>1,129 : 70 | 16·1 : 1 |

### 2. Colour in the ligule.

In two varieties out of those experimented with, the ligule is coloured. In the first, the colour segregates in a 9 : 7 ratio, in the second in a 27 : 37 ratio. The details are given in the table.

| Theoretical ratio | Variety Colour × no colour | | $F_2$ Colour : no colour | Observed ratio Colour : no colour |
|---|---|---|---|---|
| 9 : 7 (1·2 : 1) | Muramagar | Pookhi | Total 4 families 1,646 : 1,370 | 1·20 : 1 |
| 27 : 37 (1 : 1·3) | Agartollah × C 25 | | Total 8 families 1,972 : 2,697 | 1 : 1·36 |

### 3. Colour in the pulvinus and auricles.

In two varieties experimented with, colour is found in the pulvinus and auricles, *viz.*, in the variety Bailabakri and in the variety Agartollah. These both segregate in a 9 : 7 ratio as shown in the table.

| Theoretical ratio | Variety Colour × no colour | | $F_2$ Colour : no colour | Observed ratio Colour : no colour |
|---|---|---|---|---|
| 9 : 7 (1·2 : 1) | Bailabakri | Pookhi | Total 8 families 2,667 : 2,080 | 1·2 : 1 |
| | Agartollah | C 25 | Total 7 families 2,670 : 1,999 | 1·3 : 1 |

### 4. Colour in the internode.

As in the leaf-sheath, colour in the internode is found in the epidermis, in the bundle-sheaths, in the general parenchyma, or in various combinations of these. Here again coloured internode means simply visible colour in the internode, as seen from the outside by the naked eye, irrespective of the situation of the colour. Colour has always been found dominant to its absence, and on crossing, has been found, in the varieties experimented with, to

segregate in a 3 : 1 ratio, a 9 : 7 ratio and a 27 : 37 ratio. The results are given in the table :—

| Theoretical ratio | Variety Colour × no colour | $F_2$ Colour : no colour | Observed ratio Colour : no colour |
|---|---|---|---|
| 3 : 1 | Surjamukhi × Pookhi | Total 1 family<br>731 : 261 | 2·8 : 1 |
| | Noachur × Pookhi | Total 3 families<br>867 : 332 | 2·6 : 1 |
| | Muramagar × Pookhi | Total 4 families<br>2,198 : 818 | 2·6 : 1 |
| | Bailabakri × Pookhi | Total 7 families<br>3,461 : 1,226 | 2·7 : 1 |
| 9 : 7 (1·2 : 1) | Agartollah × C 25 | Total 8 families<br>2,670 : 1,999 | 1·3 : 1 |
| 27 : 37 (1 : 1·3) | C 16 × C 25 | Total 2 families<br>468 : 634 | 1 : 1·3 |

5. Colour in outer glumes.

Simple 3 : 1 segregation, as well as 9 : 7 segregation has been found, as shown in the table.

| Theoretical ratio | Variety Colour × no colour | $F_2$ Colour : no colour | Observed ratio Colour : no colour |
|---|---|---|---|
| 3 : 1 | Surjamukhi × Pookhi | Total 1 family<br>750 : 242 | 3·0 : 1 |
| | Noachur × Pookhi | Total 3 families<br>907 : 292 | 3·1 : 1 |
| | Bailabakri × Pookhi | Total 7 families<br>3,571 : 1,116 | 3·1 : 1 |
| 9 : 7 (1·2 : 1) | Muramagar × Pookhi | Total 4 families<br>1,647 : 1,369 | 1·2 : 1 |
| | Agartollah × C 25 | Total 8 families<br>2,671 : 1,998 | 1·3 : 1 |

### 6. Colour in the inner glumes.

In many varieties with colour in the outer glumes, colour is also found in the inner glumes, apart from the spot of colour at the apex, the apiculus. This applies to all the varieties experimented with, all with colour in the outer glumes having the inner glumes also tinged with colour, and the two characters have been found to segregate together. Thus the table above applies also to the inner glumes.

### 7. Colour in the apiculus.

The apiculus or apex of the inner glumes is coloured in a large number of varieties. The colour consists of a spot at the extreme tip. As in other localizations, colour in the apiculus has been found to be due either to a single factor or to two or more interacting factors. Actual results obtained are given in the table.

| Theoretical ratio | Variety Colour × no colour | F$_2$ Colour : no colour | Observed ratio Colour : no colour |
|---|---|---|---|
| 3 : 1 | Pankhiraj × Pookhi | Total 9 families<br>1,015 . 317 | 3·2 : 1 |
| | Muramagar × Pookhi | Total 4 families<br>2,198 . 818 | 2·6 : 1 |
| | Matichak . Pookhi | Total 9 families<br>2,714 . 818 | 3·3 : 1 |
| 9 : 7<br>(1·2 : 1) | Agartollah . C 25 | 2,671 : 1,998 | 1·3 : 1 |
| 27 : 37<br>(1 : 1·3) | C 9 . C 25 | Total 2 families<br>644 : 686 | 1 : 1·06 |
| 15 : 1 | Surjamukhi . Pookhi | Total 1 family<br>946 . 46 | 20·5 : 1 |
| | Noachur × Pookhi | Total 3 families<br>1,131 : 68 | 16·6 : 1 |
| | Bulabakri × Pookhi | Total 7 families<br>1,390 . 297 | 14·7 : 1 |

## 8. Colour in the stigma.

A coloured stigma is found in a large number of varieties. The colour varies in intensity from a pale red to a deep purple. It has been found to be due to a simple factor or to several interacting factors, as shown in the table :—

| Theoretical ratio | Variety Colour × no colour | $F_2$ Colour : no colour | Observed ratio Colour : no colour |
|---|---|---|---|
| 3 : 1 | Pankhiraj × Pookhi | Total 5 families<br>1,015 : 317 | 3·2 : 1 |
| | Surjamukhi × Pookhi | Total 1 family<br>731 : 261 | 2·8 : 1 |
| | Noachur × Pookhi | Total 3 families<br>870 : 329 | 2·6 : 1 |
| | Muramagar × Pookhi | Total 4 families<br>2,198 : 818 | 2·6 : 1 |
| | Matichak × Pookhi | Total 9 families<br>2,703 : 829 | 3·2 : 1 |
| | Bailabakri × Pookhi | Total 7 families<br>3,485 : 1,202 | 2·8 : 1 |
| 27 : 37 (1 : 1·3) | C 16 × C 25 | Total 2 families<br>471 : 631 | 1 : 1·5 |
| 81 : 175 (1 : 2·1) | C 9 × C 25 | Total 2 families<br>469 : 861 | 1 : 1·8 |

Summary.

In our experiments the colour in these different situations has been found to be due to a simple factor, segregating 3 : 1 in $F_2$, or to two, three, and in one case to four interacting factors, giving ratios of 9 : 7, 27 : 37, 81 : 175 and 15 : 1. Moreover, the genetic constitution of a colour character in any one type is no index of its constitution in another type, the same character having in different types been found to give most of the above ratios.

### The combination of colour characters.

Hitherto we have dealt with the inheritance of these colour characters independently of each other. It is, however, when we consider them in

relation to each other, that most interest attaches to them. We give in the Appendix (I) a table showing the various combinations of colour characters which have been found in 211 varieties critically examined. On examination, it is found that certain combinations occur more frequently than others, while on the other hand certain combinations are never found. The most frequent combination is that of the leaf-sheath and apiculus of the inner glumes. This combination occurs together in 162 varieties out of the 211 examined. The next most common combinations are the leaf-sheath, internode and apiculus which are found together in 154 varieties, and the leaf-sheath, apiculus and stigma occurring together 98 times. Conversely, it is to be noted that certain combinations are absent, *e.g.*, colour in the leaf-sheath and stigma is never found without colour in the apiculus, though the apiculus may be coloured without colour in the leaf-sheath or stigma. It is therefore to be expected that, on crossing with colourless varieties, these combinations will ordinarily be found to stick together as patterns, while, conversely, other combinations, which should be found if independent segregation is taking place, will be lacking. This has been found to be the case.

In the experiments detailed below, the following combinations have been worked with (*cf.* Appendix II):—

1. Variety Pankhiraj—coloured* leaf-sheath, coloured apiculus, coloured stigma (Fig. 1).
2. Variety Matichak—coloured leaf-sheath, coloured apiculus, coloured stigma (Fig. 2).
3. Variety Noachur—coloured leaf-sheath, internode, outer glumes, inner glumes, apiculus, stigma (Fig. 3).
4. Variety Muramagar—coloured leaf-sheath, ligule, internode, outer glumes, inner glumes, apiculus, stigma (Fig. 4).
5. Variety Surjamukhi—coloured leaf-sheath, internode, outer glumes, inner glumes, apiculus, stigma (Fig. 5).
6. Variety Bailabakri—coloured leaf-sheath, internode, pulvinus and auricle, outer glumes, inner glumes, apiculus, stigma (Fig. 6).
7. Agartollah—coloured leaf-sheath, internode, pulvinus and auricles, ligule, outer glumes, inner glumes, apiculus (Fig. 7).

The first six have in each case been crossed with a wholly green variety, Pookhi, while the seventh has been crossed with a green variety, C 25, and

* In the descriptions the word "coloured" only is used, but the colours themselves vary and the exact nature of colour can be seen by a reference to the plate.

pure-line material has been used throughout. These crosses will be described in order.

1. Variety Pankhiraj × Variety Pookhi. The system "coloured leaf-sheath, apiculus, stigma" has been found to stick together absolutely, giving 3 coloured plants : 1 green plant in $F_2$, the total of 5 families giving 3·2 coloured : 1 green (*cf.* tables above and Appendix II).

2. Variety Matichak × Var. Pookhi. The same combination behaves the same way as in No. 1, the total of nine families giving 3·2 coloured : 1 green.

3. Variety Noachur × Var. Pookhi.

(A) The system "leaf-sheath and apiculus" sticks together (2 exceptions were found out of 1,199 plants, *viz.*, two plants with coloured apiculus but green leaf-sheath) and segregates 15 coloured : 1 green in $F_2$ (total of 3 families gave 16·1 coloured : 1 green).

(B) The system "internode and stigma" sticks together (3 exceptions were found out of 1,199 plants, *viz.*, three plants with coloured stigma and green internode) segregating 3 coloured : 1 green (total three families gave 2·6 : 1).

(C) The colour in the outer and inner glumes gives 3 coloured : 1 green (total of three families gave 3·1 : 1).

In this variety there are thus three systems : (1) "leaf-sheath and apiculus" (2) "internode and stigma" (3) "outer and inner glumes." We shall call these A, B, C and treat each in relation to the other two.

I. A and B. A alone segregates 15 : 1, B alone segregates 3 : 1. On crossing with a colourless type (ab), we should therefore get, if A and B are due to different factors segregating independently of each other—

15 A : 1 a
3 B : 1 b
45 AB : 3 aB : 15 Ab : 1 ab.

Actually observed, 870 AB : O aB : 261 Ab : 68 ab (3 families of 1,199 plants).

The class aB (*i.e.*, the combination of "green leaf-sheath and apiculus" with "coloured internode and stigma") is absent.

This result can be brought about if system B (internode and stigma) is due to a single factor, and system A (leaf-sheath and apiculus) is due to two factors, *viz.*, to the factor responsible for B, together with a further factor, interacting with the factor responsible for B in such a way that both or either produces colour. This is the same as saying that one factor is

common to both, or that, if there are two factors, they must be completely linked. We get thus :—

| | | 15 A | | | : | 1 a |
|---|---|---|---|---|---|---|
| | | AB | : aB : | Ab | : | ab |
| | | 9 | : 3 : | 3 | : | 1 |
| | | 12B | | 4 b | | |
| or | .. | 12AB | : 0aB : | 3 Ab | : | 1 ab |
| Observed | .. | 870 | : 0 : | 264 | : | 68 (3 families of 1,199 plants) |
| Expect | .. | 899·04 | : 0 : | 224·76 | : | 74·92 |

The above is a common mode of segregation, occurring frequently in many varieties. It is to be noted that the combination which is wanting is one which does not occur in the 211 varieties examined (*cf.* Appendix I).

II. A and C. The case is exactly comparable to I, system A segregating 15 : 1, system C, 3 : 1

| | | AC | : aC | : Ac | : ac | |
|---|---|---|---|---|---|---|
| Observed | .. | 907 | : 0 | : 224 | : 68 | (1,199 plants, 3 families) |
| Expect | .. | 899·16 | : 0 | : 224·79 | : 74·93 | |
| Ratio | .. | 12 | : 0 | : 3 | : 1 | |

Again the combination wanting, *viz.*, "green leaf-sheath and apiculus" (*a*) with "coloured outer glumes" (C), is not found in the 211 varieties examined.

III. B and C Both segregate 3 : 1. We therefore expect, if independent segregation is taking place—

| | | BC | : Bc | : bC | : bc | |
|---|---|---|---|---|---|---|
| | | 9 | : 3 | : 3 | : 1 | |
| Observed | .. | 648 | : 222 | : 259 | : 70 | (1,199 plants, 3 families) |
| Expect | .. | 674·37 | : 224·79 | : 224·79 | : 74·93 | |

Segregation is independent and all combinations occur in their expected ratios.

4. Variety Muramagar × Var. Pookhi.

(A) The system "leaf-sheath, internode, apiculus and stigma" sticks together absolutely, giving 3 coloured : 1 colourless (total 4 families, 2·6 : 1).

(B) The colour in the ligule segregates 9 coloured : 7 colourless (total 4 families, 1·2 : 1).

(C) The colour in the outer and inner glumes gives 9 coloured : 7 colourless (total 4 families, 1·2 : 1).

I. A and B. A segregates 3 : 1, B 9 : 7. If A and B are due to separate factors, segregating independently, we should get—

| | | | | | |
|---|---|---|---|---|---|
| | A 3 : | 1 a | | | |
| | B 9 : | 7 b | | | |
| | 27 AB : | 9 aB : | 21 Ab : | 7 ab | |
| Actually observed .. | 1,646 : | 0 : | 552 : | 818 | (4 families of 5,016 plants) |

The combination of "green leaf-sheath, internode, apiculus, and stigma" (*a*) with "coloured ligule" (B) does not occur.

This again can be brought about if system A is due to a single factor, and system B to the same factor, together with a second factor interacting with the factor responsible for A in such a way that the presence of both is necessary for the production of colour. Thus again one factor is common to both, or the two factors must be completely linked. We thus get

| | | 12 A | | | 4 a | | |
|---|---|---|---|---|---|---|---|
| | | AB : | Ab : | aB : | ab | | |
| | | 9 : | 3 : | 3 : | 1 | | |
| | | 9B : | | 7b | | | |
| or | ... | 9AB : | 3Ab : | 0 aB : | 4 ab | | |
| Observed | .. | 1,646 : | 552 : | 0 : | 818 | (4 families of 3,016 plants) | |
| Expect | .. | 1,696·5 : | 565·5 : | 0 : | 754 | | |

II. A and C. A segregates 3 : 1, C 9 : 7. This case is exactly comparable to the former—

| | | 12 A | | | 4 a | | |
|---|---|---|---|---|---|---|---|
| | | AC : | Ac : | aC : | ac | | |
| | | 9 : | 3 : | 3 : | 1 | | |
| | | 9 C : | | 7c | | | |
| or | ... | 9 AC : | 3 Ac : | 0 aC : | 4 ac | | |
| Observed | ... | 1,647 : | 551 : | 0 : | 818 | (4 families of 3,016 plants) | |
| Expect | .. | 1,696·5 : | 565·5 : | 0 : | 754 | | |

The combination of "green leaf-sheath, internode, apiculus and stigma" (a) with "coloured outer glumes" (C) does not occur.

III. B and C. B segregates 9 : 7, C 9 : 7, so if segregating independently the expected ratio is—

| | | 9 B : 7 b | | | |
|---|---|---|---|---|---|
| | | 9 C : 7 c | | | |
| | | 81 BC : 63 Bc : 63 bC : 49 bc | | | |
| Observed | 1,253 | : 393 | : 394 | : 976 | (4 families of 3,016 plants) |
| Expect | 954·3 | : 742·21 | : 742·21 | : 577·27 | |

Here the expected combinations are all present, though not in the expected ratios. There are too many of the parental types, BC and bc, and too few of the cross-over types. The actual ratios obtained in the four different families were as follows :—

| | BC | : Bc | : bC | : bc |
|---|---|---|---|---|
| 1. | 92 | : 36 | : 27 | : 90 |
| 2. | 196 | : 58 | : 48 | : 118 |
| 3. | 834 | : 266 | : 296 | : 714 |
| 4. | 131 | : 33 | : 23 | : 54 |
| TOTAL | 1,253 | : 393 | : 394 | : 976 |

The figures are somewhat irregular, but on examination some of the ratios obtained are found to be a fairly close approximation to expectation on a basis of a 7 : 1 coupling of the parental gametes. On this basis the expected ratios are—

| | | | | |
|---|---|---|---|---|
| 1. | 122·81 | : 30·93 | : 30·93 | : 60·33 |
| 2. | 210·53 | : 53·14 | : 53·14 | : 103·39 |
| 3. | 1057·69 | : 266·44 | : 266·44 | : 519·42 |
| 4. | 120·80 | : 30·44 | : 30·44 | : 59·32 |

To definitely prove the gametic constitution of the $F_1$, it would be necessary to backcross it with the recessive parent, a very laborious undertaking in the case of a cereal like rice, as each cross results only in the production of one fertilized seed, and to obtain only 100 plants would require 100 crossings, and that assuming all were successful and all seeds germinated and reached maturity.

5. Variety Surjamukhi × Variety Pookhi.

(A) The combination "leaf-sheath, internode and stigma" sticks together absolutely, giving 3 coloured : 1 colourless (992 plants gave 2·8 : 1).

(B) Colour in outer and inner glumes gives 3 coloured : 1 colourless (992 plants gave 3 : 1).

(C) Colour in the apiculus gives 15 : 1 (992 plants gave 20 : 1).

I. A and B. A segregates 3 : 1, B 3 : 1. If independent segregation takes place, we expect—

| | 9 AB : | 3 Ab : | 3 aB : | 1 ab | |
|---|---|---|---|---|---|
| Observed .. | 535 | : 196 | : 215 | : 46 | (992 plants) |
| Expect .. | 558 | : 186 | : 186 | : 62 | |

Segregation is independent according to expectation.

II. A and C. A segregates 3 : 1, C 15 : 1. If independent segregation takes place, the expected ratio is—

| | 3 A : | 1 a | | | |
|---|---|---|---|---|---|
| | 15 C : | 1 c | | | |
| | 45 AC : | 15 aC : | 3 Ac : | 1 ac | |
| Observed .. | 731 | : 215 | : 0 | : 46 | (992 plants) |

The combination of "green apiculus" (*c*) with "coloured leaf-sheath, internode and stigma" (A) is not found. As in former cases of the sort, A is due to a single factor, C to a second factor interacting with the factor responsible for A in such a way that either or both produces colour. Thus

| | 12 A : | | 4 a | |
|---|---|---|---|---|
| | AC : | Ac : | aC : | ac |
| | 9 : | 3 : | 3 : | 1 |
| | 15 C | | | : 1 c |
| or .. | 12 AC : | 3 aC : | 0 Ac : | 1 ac |
| Observed .. | 731 | : 215 | : 0 | : 46 |
| Expect .. | 744 | : 186 | 0 | : 62 |

III. B and C. B segregates 3 : 1, C 15 : 1, so this case is exactly comparable to II.

| Ratio .. | 12 BC : | 3 bC : | 0 Bc : | 1 bc | |
|---|---|---|---|---|---|
| Observed .. | 750 | : 196 | 0 | : 46 | (992 plants) |
| Expect .. | 744 | : 186 | : 0 | : 62 | |

The combination of "coloured outer glumes" (B) with "colourless apiculus" (*c*) is not found.

6. Variety Bailabakri × Pookhi.

(A) The combination "leaf-sheath, internode, stigma" sticks together (24 exceptions out of 4,687 had green internodes) and gives 3 coloured : 1 colourless (total 7 families, 2·8 : 1).

(B) The " pulvinus and auricles " stick together, giving 9 coloured : 7 colourless (total 7 families, 1·2 : 1).

(C) Coloured outer and inner glumes give 3 coloured : 1 colourless (total 7 families, 3·1 : 1).

(D) Coloured apiculus gives 15 coloured : 1 colourless (total 7 families, 14·7 : 1).

I. A and B. A segregates 3 : 1, B 9 : 7. If independent segregation takes place, we expect—

| | 27 AB : | 9 aB : | 21 Ab : | 7 ab | |
|---|---|---|---|---|---|
| Observed .. | 2,607 | 0 | 878 | 1,202 | (7 families of 4,687 plants) |

The combination of " coloured pulvinus and auricles" (B) with " green leaf-sheath, internode, stigma " (*a*) is not found.

This case is comparable to previous ones. A is due to a single factor, B to a second additional factor interacting with the factor responsible for A in such a way that the presence of both is necessary for the production of colour. Thus we get

| | 12 A | | 4 a | |
|---|---|---|---|---|
| | AB : | Ab : | aB : | ab |
| | 9 : | 3 : | 3 : | 1 |
| | 9 B : | | 7 b | |
| or .. | 9 AB : | 3 Ab : | 0 aB : | 4 ab |
| Observed .. | 2,607 : | 878 : | 0 : | 1,202 |
| Expect .. | 2,636·43 : | 878·81 : | 0 : | 1,171·75 |

II. A and C. A segregates 3 : 1, C 3 : 1.

| | | | | | |
|---|---|---|---|---|---|
| Expected ratio | 9 AC : | 3 Ac : | 3 aC : | 1 ac | |
| Observed .. | 2,666 | 819 | 905 | 297 | (7 families of 4,687 plants) |
| Expect .. | 2,636·37 | 878·79 | 878·79 | 292·93 | |

Segregation is independent and according to expectation.

III. A and D. A segregates 3 : 1, D 15 : 1, so expected ratio, if independent segregation takes place, is—

| | 3 A : | 1 a | | | |
|---|---|---|---|---|---|
| | 15 D : | 1 d | | | |
| | 45 AD : | 15 aD : | 3 Ad : | 1 ad | |
| Observed .. | 3,485 | 905 | 0 | 297 | (7 families of 4,687 plants) |

Here the combination of "green apiculus" (d) with " coloured leaf-sheath, internode, stigma " (A) is not found.

A is again due to a single factor, D to a second additional factor interacting with the factor for A, both or either producing colour. Thus

| | | 12 A | | | | 4 a | | |
|---|---|---|---|---|---|---|---|---|
| | | AD | : Ad | : aD | : | ad | | |
| | | 9 | : 3 | : 3 | : | 1 | | |
| | | 15 D | : | | | 1 d | | |
| or | .. | 12 AD | : 3 aD | : 0 Ad | : | 1 ad | | |
| Observed | ... | 3,485 | : 905 | : 0 | : | 297 | (7 families of plants) | 4,687 |
| Expect | .. | 3,515·16 | : 878·79 | : 0 | : | 292·93 | | |

IV. B and C. B segregates 9 : 7, C 3 : 1. If independent segregation takes place, the expected ratio is—

| | | 27 BC | : 21 bC | : 9 Bc | : 7 bc | | |
|---|---|---|---|---|---|---|---|
| Observed | .. | 1,992 | : 1,579 | : 615 | : 501 | (7 families of plants) | 4,687 |
| Expect | ... | 1,977·33 | : 1,537·92 | : 659·1 | : 512·64 | | |

Here all expected combinations are found in expected ratios.

V. B and D. B segregates 9 : 7, D 15 : 1, so if independent segregation takes place, the expected ratio is—

| | | 135 BD | : 105 bD | : 9 Bd | : 7 bd | | |
|---|---|---|---|---|---|---|---|
| Observed | .. | 2,607 | : 1,783 | : 0 | : 297 | (7 families of plants) | 4,687 |

The combination " coloured pulvinus and auricles " (B) with "green apiculus " (d) does not occur.

If B is due to two interacting factors, both necessary for the production of colour, and D due to the same two, but either alone capable of producing colour, we get the required result. Thus—

| | | 9 B | : | 7b | | |
|---|---|---|---|---|---|---|
| | | BD | : Bd | : bD | : bd | |
| | | 9 | : 3 | : 3 | : 1 | |
| | | 15 D | | | : 1 d | |
| | | 9 BD | : 6 bD | : 0 Bd | : 1 bd | |
| Observed | .. | 2,607 | : 1,783 | : 0 | : 297 | |
| Expect | .. | 2,636·37 | : 1,757·58 | : 0 | : 292·93 | |

VI. C and D. C gives 3 : 1, D 15 : 1, so expected ratio, if segregating independently, is

| | 45 CD | : | 15 cD | : | 3 Cd | : | 1 cd | |
|---|---|---|---|---|---|---|---|---|
| Observed .. | 3,571 | : | 819 | : | 0 | : | 297 | (7 families of 4,687 plants) |

The combination of coloured glumes (C) with green apiculus (d) does not occur.

This is the same as previous cases, *viz.*, C due to a single factor, D to two factors, the factor responsible for C and an additional one, both or either capable of producing colour. Thus—

| | 12 C | | | 4 d | | | |
|---|---|---|---|---|---|---|---|
| | CD | : | Cd | : | cD | : | cd |
| | 9 | : | 3 | : | 3 | : | 1 |
| | 15 D | | | : | 1 d | | |
| | 12 CD | : | 3 cD | : | 0 Cd | : | 1 cd |
| Observed | 3,571 | : | 819 | : | 0 | : | 297 (7 families of 4,687 plants) |
| Expected | 3,515·16 | : | 878·79 | : | 0 | : | 292·93 |

7. Variety Agartollah × Variety C25.

(A) The combination "leaf-sheath, pulvinus, auricles, internode, outer glumes, inner glumes, apiculus" sticks together (1 exception was found in 4,669 plants examined, *viz.*, one plant with coloured apiculus and coloured glumes, but green leaf-sheath, internode, pulvinus and auricle), giving 9 coloured : 7 colourless (total 8 families, 1·3 : 1).

(B) The ligule gives 27 coloured : 37 colourless (total 8 families 1 : 1·3).

I. A and B. A segregates 9 : 7, B 27 : 37. If independent segregation takes place, the expected ratio is

| | A 9 | : | 7 a | | | | |
|---|---|---|---|---|---|---|---|
| | B 27 | : | 37 b | | | | |
| | 243 AB | : | 189 aB | : | 333 Ab | : | 259 ab |
| Observed .. | 1,972 | : | 0 | : | 699 | : | 1,998 (4,669 plants, 7 families) |

The combination of "green leaf-sheath, pulvinus, auricles, internode, outer glumes, apiculus" (a) with coloured ligule (B) does not occur.

Here A is due to two interacting factors, B to three, *viz.*, the two responsible for A together with an additional one, all three being necessary for the production of colour in B. Thus—

| | 36 A : | | | | 28 a | | | |
|---|---|---|---|---|---|---|---|---|
| | ABC : | ABc : | AbC : | aBC : | Abc : | aBc : | abC : | ab |
| | 27 : | 9 : | 9 : | 9 : | 3 : | 3 : | 3 : | 1 |

| | 27 B : | 37 b | |
|---|---|---|---|
| or .. | 27 AB : | 9 Ab : 0 aB : | 28 ab |
| Observed .. | 1,972 : | 699 : 0 : | 1,998 (4,669 plants, 7 families) |
| Expect .. | 1,969·29 : | 656·43 : 0 : | 2,042·25 |

## Summary.

1. These colour characters which we have been discussing are sometimes simple, due to single factors or to several interacting factors. But frequently they are grouped into patterns or systems (*e.g.*, "leaf-sheath, apiculus, stigma"), which are inherited as a whole and segregate as if due to a single unit factor or to the same interacting factors. There is evidence, however, that the constituent parts of these patterns may be due to different factors, in which case they must be completely linked. The evidence consists, first, in the fact that rare instances are found where the patterns break down. Four such cases have been found (1) In the cross Noachur × Pookhi, the pattern "coloured internode and stigma" was found to break down three times out of 1,199 plants examined, giving 3 types in $F_2$ with "coloured stigma and green internode". (2) In the same cross the pattern "coloured leaf-sheath and apiculus" broke down twice out of 1,199 plants, giving two types in $F_2$ with "coloured apiculus and green leaf-sheath." (3) In the cross Bailabakri × Pookhi, the pattern "coloured leaf-sheath, internode and stigma" broke down 24 times out of 4,687 plants examined, giving 24 plants with coloured leaf-sheath and stigma but green internode. (4) In the cross Agartollah × C25 the pattern "coloured leaf-sheath, pulvinus, auricles, internode, glumes, apiculus" broke down once out of 4,669 plants examined, *viz.*, one plant was found with colour in the glumes and apiculus, but with green leaf-sheath, internode, pulvinus and auricles.

These exceptional cases might be simply mistakes in observation but all were very carefully examined and if colour was present, it must have been developed to so small a degree that it could not be observed by the most critical examination, whereas the type plants had the colour strongly developed. It is to be noted, moreover, that all are cases in which colour failed

to develop in some part of the pattern, so they could not be due to accidental crossing, and moreover, the $F_1$ plants, though not bagged, were grown isolated in pots. Accidental mixture too is ruled out, as we have no such types. It would seem, therefore, that they are real breaks in the pattern systems, or, at any rate, extreme negative variations in the development of colour in the part concerned. If, however, they are breaks in the pattern systems and the patterns are due to one unit factor, it is difficult to understand by what mechanism these constituent parts of the pattern can break away, as they appear occasionally to do. Another case of a break in correlation is discussed below under grain colour, *viz.*, between red colour in the grain and colour in the ligule of the leaf. Similar cases of breaks in colour correlation have been described by Parnell[1] in rice ; and in other plants, notably by Emerson[2] in maize.

Again, it has been proved that in same varieties localizations such as leaf-sheath, apiculus and stigma stick together absolutely and belong to the same system, as in the crosses Pankhiraj × Pookhi and Matichak × Pookhi, where this pattern segregates 3 : 1 in $F_2$ (Nos. 1 and 2 discussed above) ; but again in variety Noachur × Pookhi (No. 3 above) and others, the leaf-sheath and apiculus belong to a different system from the stigma, a system due to two interacting factors, segregating 15 : 1 ; whereas the stigma is united with the internode, and is due to a single factor and segregates 3 : 1.

2. These patterns or systems have been shown sometimes to segregate independently of other systems, giving all expected combinations in expected ratios in $F_2$, but frequently certain expected combinations are wanting, and the wanting combinations have been shown to be those which never occur in pure-line cultures. Examples of this are cases such as the cross Noachur × Pookhi.

In Noachur the system "leaf-sheath and apiculus" (A) segregates 15 : 1 ; the system "internode and stigma" (B) segregates 3 : 1.

On crossing with a colourless type (ab) you expect, if independent segregation is taking place,

15 A : 1 a
3 B : 1 b
45 AB : 3 aB : 15 Ab : 1 ab

[1] Parnell, F. R., Ayyangar, G. N. R. and Ramiah, K. "The Inheritance of Characters in Rice. I. *Mem. Dept. Agri. India, Bot. Ser.*, Nov. 1917, vol. IX, no. 2.

[2] Emerson, R. A. "Genetic Correlation and Spurious Allelomorphism in Maize. *Twenty-fourth Ann. Rep., Agri. Exper. Station, Nebraska*, 1911, pp. 59—82.

Actually the combination of aB (green leaf-sheath and apiculus with coloured internode and stigma) is absent, and the ratio obtained is—

48 AB : 0 aB : 12 Ab : 4 ab

In such cases we must be dealing either with three factors, two of which are completely linked, or one factor is common to both systems, while a second additional factor, interacting with the common factor in such a way that the presence of either is sufficient for the production of colour, is responsible for the colour in the system "leaf-sheath and apiculus" (thus segregating 15 : 1). Thus—

| | 15 A | | | 1 a |
|---|---|---|---|---|
| | AB : | aB : | Ab : | ab |
| | 9 : | 3 : | 3 : | 1 |
| | 12 B | | 4 B | |
| or ... | 12 AB : | 0 aB : | 3 Ab : | 1 ab |

This type of segregation occurs very frequently.

Lastly, one instance has been found, *viz.*, in the cross Muramagar × Pookhi, in which the parental combinations (in this case coloured ligule and coloured outer and inner glumes ; colourless ligule and colourless glumes) occur more frequently than expectation if independent segregation is taking place, some of the ratios obtained indicating a coupling of the parental gametes in the neighbourhood of 7 : 1.

The final conclusions are—

1. These colour characters are frequently inherited in patterns of groups, due either to one and the same simple factor or to the same interacting factors ; or due to several factors linked together.

2. Considered in relation to other systems or patterns, independent segregation may take place, but frequently the groups are so inter-related that certain combinations, expected if independent segregation were taking place, are never found, and these combinations are those which are absent in pure-line cultures.

## Grain colour.

The husked grain of rice is either some shade of red or white. A large number of crosses, both natural and artificial, have been examined with reference to grain colour and in all, with two exceptions, simple, independent 3 : 1 segregation has been found. As the inheritance of this character, with

the exception of the cases referred to, presents no special interest, this account is confined to the exceptions.

1. The first of these was found in the cross Agartollah × C25 already described in connection with colour of the vegetative parts. In variety Agartollah, the grain is dark red with irregular black marks on the ventral edge giving the grain a slightly piebald appearance. On crossing with the colourless variety C25 (white grain), the $F_1$ is like the Agartollah grain but paler in colour, and in $F_2$ segregation is into 1 red piebald : 2 pale piebald : 1 white.

Actual figures obtained in three families examined for grain colour are given below :—

| | Red piebald | Pale piebald | White |
|---|---|---|---|
| 1 .. | 141 | 329 | 149 |
| 2 .. | 153 | 360 | 184 |
| 3 .. | 177 | 342 | 177 |
| TOTAL | 471 | 1,031 | 510 |

It is, however, when we consider the relation of the grain colour to the colours in the vegetative parts, already described, that most interest attaches to this case.

We have already seen in variety Agartollah that the leaf-sheath, pulvinus and auricle, internode, outer glumes and apiculus form a pattern (A), due to 2 interacting factors and segregating 9 : 7 in $F_2$, while the ligule (B) is due to 3 factors and segregates 27 : 37, together giving, on crossing with the colourless (green) type Pookhi—

36 coloured leaf-sheaths, etc. (A) : 28 green leaf-sheaths (a)

| ABC | ABc | AbC | aBC | abC | Abc | aBc | abc |
|---|---|---|---|---|---|---|---|
| 27 | 9 | 9 | 9 | 3 | 3 | 3 | 1 |

27 coloured ligules (B) : 37 green ligules (b)

or .. 27 AB : 9 Ab : 0 aB : 28 ab

When we examine the distribution of the grain colour with reference to the above, we find, with a few exceptions, all class AB (coloured leaf-sheath, coloured ligule) have coloured grains ; all class Ab (coloured leaf-sheath, colourless ligules) have white grains ; all class ab (both colourless) have coloured and white grains in a ratio of 3 : 1. All white grains therefore, with

the few exceptions noted, are associated with colourless ligules, but not *vice versâ*.

The actual numbers observed in 4 families were as follows :—

| | 27 AB | : | 9 Ab | : | 28 ab |
|---|---|---|---|---|---|
| Observed | 1,226 .. | : | 414 | : | 1,267 (4 families of 2,907 plants) |

| Coloured grain—white grain | | : | White grains | : | Coloured grains—white grains | |
|---|---|---|---|---|---|---|
| 1,220 | 6 | | 414 | | 951 | 316 |
| 27ABC | | | 9Abc | 9AbC, 9aBC, 3abC | 3Abc, 3aBc, 1abc | |
| Expect | 1226·37 | | 408·79 | 953·85 | 317·95 | |

It thus appears that the factor responsible for colour in the grain is the third or C factor responsible for colour in the ligule. When C is present, the grain is coloured (with the six exceptions noted) ; when C is absent, the grain is white. Thus the colour in the grain must be due to this factor C, or to a factor completely linked with it. In this connection, the six exceptions with coloured ligules and white grains, are important, as furnishing further evidence in support of the latter view, for if one and the same factor is responsible for both ligule and grain, it is difficult to conceive by what mechanism these exceptions could come about. On the other hand, if two linked factors are responsible, then these exceptions are simply rare instances of breaks in the linkage, such as have already been noted above in the case of the colour patterns in the vegetative parts, in which some of the constituent parts have been seen occasionally to break away.

2. The second exceptional case has been found in the cross C9 × C 25. Here the parent C9 had a dark red grain, C25 a white. On crossing, the $F_1$ was like the C9 grain but paler, and in F segregated into four types of grain, dark red, pale red, pale amber and pure white. The figures obtained in 3 families examined are given in the table—

| | Dark red | Pale red | Pale amber | White |
|---|---|---|---|---|
| 1 .. | 69 | 150 | 15 | 10 |
| 2 .. | 48 | 119 | 34 | 25 |
| 3 .. | 67 | 87 | 36 | 25 |
| Total | 184 | 356 | 85 | 60 |
| | | | 177 | |
| Ratio | 1 | 2 | 1 | |

In this case the figures again approximate to a 1 : 2 : 1 ratio for red, pale red, and white, but the white class appears to be of two sorts, *viz.*, a pale amber class and a pure white.

SUMMARY.

Red colour in the grain ordinarily gives simple 3 : 1 segregation in $F_1$, and segregates independently of colour in the vegetative parts. Two cases, however, have been found in which segregation in $F_2$ is into 1 red : 2 pale red : 1 white, and in one of these, the white are of two sorts, in equal numbers. In the other, the colour in the grain has been proved to be due either to the same factor which is responsible for colour in the ligule, or to a factor completely linked with this factor. The fact that there are found a few cases of plants with coloured ligules and white grains, is evidence in favour of the latter view.

## Colour of ripe glumes.

The colour of the ripe glumes of rice, *i.e.*, the husk, is generally some shade of yellow, red or black, or a mixture of these. The colour is often uniform, but piebald grains are frequent.

These ripe glume colours have been studied in all the seven varieties discussed above with reference to colour in the vegetative parts, and those in which definite results have been obtained are described below, together with a few others.

1. Variety Pankhiraj × Pookhi. Variety Pankhiraj ripens brownish-black (Fig. 1); variety Pookhi ripens yellow-brown. On crossing, the ripe $F_1$ glume is like Pankhiraj, brown-black, and in $F_2$ segregation is complete into 3 Pankhiraj glumes : 1 Pookhi glume. Actual figures obtained are given in the table.

| Parents | F: Brown-black : Yellow-brown | Ratio |
|---|---|---|
| Pankhiraj × Pookhi | 69 : 26 | |
| | 157 : 52 | |
| | 206 : 57 | |
| | 93 : 23 | |
| Total | 525 : 158 | 3·3 : 1 |

We have seen above that the colour in the vegetative parts of Pankhiraj forms a pattern, *viz.* "coloured leaf-sheath, apiculus, stigma," segregating 3 coloured : 1 green in $F_2$. Considered in relation to this colour in the vegetative parts, we find the colour of the ripe glumes segregates independently, giving 9 coloured, black : 3 coloured, yellow-brown : 3 green, black : 1 green, yellow-brown. Actual numbers observed were 401 coloured black : 114 green, black : 113 coloured, yellow-brown : 44 green, yellow-brown.

2. Variety Matichak × Pookhi. The ripe glume of Matichak (Fig. 2) is almost indistinguishable from that of Pankhiraj, and segregation is in the same simple 3 : 1 ratio of black : yellow-brown, and independent of colour in the vegetative parts, as in No. 1.

Actual figures obtained in three families examined were—

| | Coloured plants Black glumes | Coloured plants Yellow glumes | Green plants Black glumes | Green plants Yellow glumes |
|---|---|---|---|---|
| | 225 | 59 | 64 | 30 |
| | 279 | 72 | 127 | 27 |
| | 202 | 47 | 48 | 16 |
| TOTAL | 706 | 178 | 239 | 73 |

3. Variety Noachur × Pookhi. Here the glume colour of both parents is almost indistinguishable and incapable of analysis in $F_2$.

4. Variety Muramagar × Pookhi. The glume colour of both parents is almost indistinguishable and incapable of analysis.

5. Variety Surjamukhi × Pookhi. The ripe glume of Surjamukhi is a brick-red colour ( Fig. 5 ). In the $F_1$ of this cross, the Pookhi glume (yellow-brown) is dominant, and in $F_2$ segregation is into 3 Pookhi glumes : 1 Surjamukhi.

Actually observed 742 : 250.

Here again the ripe glume colour segregates independently of the colour in the vegetative parts, which have already been described. At flowering time, the glumes which ripen yellow-brown are pure green in colour, those which ripen red are a golden green.

6. Variety Bailabakri × Pookhi. The glume colours of both parents are almost indistinguishable, and analysis is not possible in $F_2$.

7. Variety Agartollah × Pookhi. The glume colours of both parents are almost indistinguishable and analysis is not possible.

In addition to the above, two other crosses have been examined with reference to ripe glume colour, and have given definite results. These are described below.

1. Rajshahi 22 × Bogra 17. Rajshahi 22 has glumes ripening brick-red like Surjamukhi, Bogra ripens yellow. Both varieties are colourless (green) as regards the growing vegetative parts. In $F_1$, yellow ripe glumes are dominant, and in $F_2$ segregation is as shown below.

Rajshahi 22 × Bogra 17

| Yellow | Intermediate (yellow & red) | Red |
|---|---|---|
| 58 | 52 | 7 |
| 96 | 58 | 9 |

An exactly similar result was obtained on crossing the same Rajshahi 22 with another variety with similar yellow-coloured glumes.

Rajshahi 22 × Chittagong 22

| Yellow | Intermediate (yellow & red) | Uniform Red |
|---|---|---|
| 88 | 61 | 9 |
| 82 | 58 | 14 |
| 47 | 26 | 8 |
| Total of both 371 | 255 | 47 |

On examination it is seen that the figures closely approximate to a ratio of 9 yellow : 6 intermediate : 1 red, the expectation on this basis being 378·5 : 255·44 : 42·06.

On the above basis, the following results should obtain in $F_3$. The yellow will be of three constitutions (1) pure yellow AB, (2) yellow impure for one factor, AaBB or AABb. (3) yellow impure for both, as in $F_1$. These types will give (1) pure yellow, (2) 3 yellow : 1 intermediate, (3) 9 yellow : 6 intermediate : 1 red. Reds being recessive will give reds only.

The following actual results were obtained from $F_2$ yellow and red-glumed plants.

| $F_2$ 1917 | Yellow | Intermediate | Red | Ratio |
|---|---|---|---|---|
| YELLOW— | | | | |
| 2 families .. | 182 | – | | Pure yellow |
| | 94 | — | — | |
| 8 families .. | 215 | 67 | – | |
| | 208 | 59 | – | Yellow : Intermediate |
| | 90 | 30 | – | 1,222 : 318 |
| | 114 | 43 | | expected |
| | 81 | 26 | – – | 1201·5 . 401·5 |
| | 140 | 41 | | 3 : 1 |
| | 134 | 43 | | |
| | 240 | 71 | — | |
| 5 families .. | 105 | 60 | 8 | Yellow : Intermediate : Red |
| | 94 | 70 | 6 | 638 : 373 : 51 |
| | 61 | 46 | 4 | expected |
| | 239 | 129 | 20 | 597·5 398·2 : 66·3 |
| | 139 | 68 | 13 | 9 : 6 1 |
| RED— | | | | |
| 8 families .. | .. | .. | 91 | |
| | .. | .. | 193 | |
| | .. | .. | 144 | Yellow : Intermediate : Red |
| | .. | .. | 296 | 8 : 7 : 1,544 |
| | 3 | 1 | 205 | expected |
| | 2 | 2 | 251 | pure red |
| | 2 | 4 | 268 | |
| | 1 | .. | 96 | |

The excess of yellows in the families from yellow parents and the small numbers of yellow and intermediate in the families from red parents can easily be explained by natural crossing, as the $F_2$ plants were not protected.

2. Variety Kataktara × Charnak. Variety Kataktara has again a brick-red husk, Charnak a pale-yellow husk. The Charnak husk is dominant, and in $F_2$ segregation is into 3 yellow : 1 red.

At flowering time the glumes which ripen yellow are pale green, those which ripen red are golden-green in colour. There is no connection otherwise between the ripe glume colours and the colours in the vegetative parts.

## Summary.

In the results discussed above, definite ratios have been obtained in five cases. In two of these, Pookhi was crossed with varieties having glumes ripening black. In both, the Pookhi husk (yellow-brown) was recessive, and segregation was into 3 black : 1 yellow-brown.

In another, Pookhi was crossed with a variety with glumes ripening red. Here Pookhi was dominant, and segregation into 3 yellow-brown : 1 red.

A similar result was obtained in the cross Charnak × Kataktara. The yellow glume of Charnak was dominant over the red of Kataktara, and segregation was into 3 yellow : 1 red.

In still another cross between yellow and red, yellow was again dominant, but segregation was into 9 yellow : 6 yellow and red : 1 pure red.

In no case has any connection been proved between the ripe glume colours and the colours in the vegetative parts previously discussed.

## APPENDIX I.

### Colour combinations of 211 coloured varieties of rice.

*I. Leaf-sheath coloured, apiculus coloured, stigma coloured.*

| Class No. | Pulvinus | Auricle | Ligule | Node | Internode | Outer glumes | Inner glumes | Awns | No. of types |
|---|---|---|---|---|---|---|---|---|---|
| 1 | — | — | × | — | — | — | — | — | 1 |
| 2 | — | — | — | — | — | — | — | — | 2 |
| 3 | × | × | — | — | — | — | — | — | 1 |
| 4 | × | — | — | — | × | — | — | — | 1 |
| 5 | — | — | — | × | × | — | — | — | 1 |
| 6 | — | — | × | — | — | — | — | × | 1 |
| 7 | × | × | — | — | × | — | — | — | 1 |
| 8 | × | × | — | × | — | — | — | — | 1 |
| 9 | × | — | — | × | × | — | — | — | 2 |
| 10 | — | — | × | × | — | — | — | — | 1 |
| 11 | — | — | — | — | — | — | — | × | 5 |
| 12 | — | — | × | — | × | — | × | — | 1 |
| 13 | × | × | × | — | — | — | — | × | 1 |
| 14 | × | × | — | — | × | — | — | — | 30 |
| 15 | × | — | × | × | × | — | — | — | 1 |
| 16 | × | — | — | — | × | — | — | × | 1 |
| 17 | × | — | — | — | × | — | — | × | 2 |
| 18 | — | — | × | — | × | — | — | × | 1 |
| 19 | × | × | × | × | × | — | — | — | 7 |
| 20 | × | × | — | × | × | — | — | × | 24 |
| 21 | × | — | × | × | × | — | — | × | 1 |
| 22 | — | × | × | — | × | — | — | × | 1 |
| 23 | × | × | — | × | × | — | × | — | 1 |
| 24 | — | — | × | × | × | × | × | × | 1 |
| 25 | × | × | × | × | × | — | — | × | 6 |
| 26 | × | × | — | × | × | × | — | × | 1 |
| 27 | × | × | — | × | × | × | × | × | 1 |
| 28 | × | × | × | × | × | × | — | × | 1 |

× = coloured.
— = green (colourless).

APPENDIX I—*concld.*

*II. Leaf-sheath coloured, apiculus coloured, stigma white.*

| Class No. | Pulvinus | Auricle | Ligule | Node | Internode | Outer glumes | Inner glumes | Awns | No. of types |
|---|---|---|---|---|---|---|---|---|---|
| 1 | — | — | — | — | × | — | — | — | 1 |
| 2 | — | — | · | — | × | — | × | — | 2 |
| 3 | — | — | — | — | — | × | × | — | 1 |
| 4 | — | — | — | — | · | × | × | — | 20 |
| 5 | · | × | — | · | × | — | · | · | 1 |
| 6 | · | — | — | × | · | × | × | — | 1 |
| 7 | · | — | · | · | × | × | × | × | 13 |
| 8 | × | · | — | · | × | × | × | — | 4 |
| 9 | · | × | · | × | × | — | × | — | 2 |
| 10 | × | · | · | — | · | · | × | × | 3 |
| 11 | × | · | · | · | · | · | × | × | 1 |
| 12 | · | · | — | × | · | · | × | — | 1 |
| 13 | · | × | · | — | × | · | · | — | 4 |
| 14 | · | × | · | · | × | × | · | — | 5 |
| 15 | × | · | · | · | — | · | · | × | 1 |
| 16 | × | × | — | — | × | · | × | × | 1 |
| 17 | · | · | · | · | × | × | · | — | 3 |

*III. Leaf sheath green, apiculus coloured, stigma white.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | — | — | — | — | — | · | · | × | 2 |
| 2 | — | — | — | · | — | × | × | — | 28 |
| 3 | — | — | — | — | — | × | — | × | 3 |
| 4 | — | — | — | — | — | × | × | × | 13 |
| 5 | × | — | — | — | — | × | × | × | 2 |
| 6 | × | × | — | — | — | × | × | — | 1 |

× = coloured.
— = green (colourless).

## APPENDIX II.

*Colour combinations in seven pure-line types of rice and in $F_2$ of crosses between them and green varieties.*

| Varieties. | Leaf-sheaths | Pulvinus | Auricle | Ligule | Internode | Outer glumes | Inner glumes | Apiculus | Stigma | No. of families examined | Total No. observed | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pookhi | | | | — | — | — | — | — | — | | | |
| C 25 | | | — | — | — | | | — | — | | | |
| Pankhiraj | | | | | — | | | × | | | | |
| Matichak | × | | — | — | — | — | — | — | | | | |
| Noachur | × | | | | | × | × | × | | | | |
| Muramagar | | | | | | | | × | | | | |
| Surjamukhi | × | | | | × | | | × | | | | |
| Bailabakri | × | × | × | | × | × | × | × | | | | |
| Agartollah | × | × | × | × | × | × | × | × | — | | | |
| Pankhiraj × Pookhi, $F_2$ | | | | | | | | | | | | |
| Class I | × | — | — | — | — | — | — | × | | 5 | 1,015 | 1,332 |
| ,, II | — | — | — | — | — | — | — | — | — | | 317 | |
| Matichak × Pookhi, $F_2$ | | | | | | | | | | | | |
| Class I | × | — | | — | — | | — | × | | 9 | 2,703 | 3,532 |
| ,, II | — | — | — | — | — | — | — | — | — | | 829 | |

× = coloured.
— = green (colourless).

APPENDIX II—*contd.*

| Varieties | Leaf-sheaths | Pulvinus | Auricle | Ligule | Internode | Outer glumes | Inner glumes | Apiculus | Stigma | No. of families examined | Total No. observed | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Noachur × Pookhi, $F_2$ | | | | | | | | | | | | |
| Class I | × | — | — | — | × | × | × | × | × | 3 | 648 | 1,199 |
| ,, II | × | — | | — | × | — | — | × | × | | 219 | |
| ,, III | × | — | | — | | — | — | × | × | | 3* | |
| ,, IV | × | — | — | — | | × | × | × | — | | 259 | |
| ,, V | — | — | | — | — | — | — | × | — | | 2* | |
| ,, VI | — | — | — | — | | | — | | — | | 68 | |
| Muramagar × Pookhi, $F_2$ | | | | | | | | | | | | |
| Class I | × | — | — | × | × | × | × | × | × | 4 | 1,253 | 3,016 |
| ,, II | × | — | — | — | × | × | × | — | × | | 394 | |
| ,, III | × | — | — | × | × | — | — | × | × | | 393 | |
| ,, IV | × | — | — | — | × | — | — | × | × | | 158 | |
| ,, V | — | — | — | — | — | — | — | — | — | | 818 | |
| Surjamukhi × Pookhi, $F_2$ | | | | | | | | | | | | |
| Class I | × | — | | — | × | × | × | × | × | 1 | 535 | 992 |
| ,, II | × | — | — | — | × | — | — | × | × | | 196 | |
| ,, III | — | — | — | — | — | × | × | × | — | | 215 | |
| ,, IV | — | — | — | — | — | — | — | — | — | | 46 | |

× = coloured.
— = green (colourless).
* Breaks in the pattern systems.

APPENDIX II—*concld.*

| Varieties | Leaf-sheaths | Pulvinus | Auricle | Ligule | Internode | Outer glumes | Inner glumes | Apiculus | Stigma | No. of families examined | Total No. observed | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bailabakri × Pookhi, $F_2$ | | | | | | | | | | | | |
| Class I | × | × | × | — | × | × | × | × | × | 7 | 1,992 | 4,687 |
| ,, II | × | — | — | — | × | × | × | × | × | | 674 | |
| ,, III | × | × | × | — | × | — | — | × | × | | 507 | |
| ,, IV | × | × | × | — | × | — | — | × | × | | 108 | |
| ,, V | × | — | — | — | × | — | — | × | × | | 180 | |
| ,, VI | × | — | — | — | — | — | — | × | × | | 24* | |
| ,, VII | — | — | — | — | — | × | × | × | — | | 905 | |
| ,, VIII | — | — | — | — | — | — | — | — | — | | 297 | |
| Agartollah × C 25, $F_2$ | | | | | | | | | | | | |
| Class I | × | × | × | × | × | × | × | × | — | 8 | 1,972 | 4,669 |
| ,, II | × | × | × | — | × | × | × | × | — | | 698 | |
| ,, III | — | — | — | — | — | — | — | — | — | | 1,998 | |
| ,, IV | — | — | — | — | — | × | × | × | — | | 1* | |

× = coloured.
— = green (colourless).
* Breaks in the pattern systems.